MEASUREMENTS TO DETERMINE POTENTIAL INTERFERENCE TO GPS RECEIVERS FROM ULTRAWIDEBAND TRANSMISSION SYSTEMS

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This report describes laboratory measurements of Global Positioning System (GPS) receiver vulnerability to ultrawideband (UWB) interference. The laboratory measurements were performed by inserting increased levels of UWB interference until an operating GPS receiver lost lock. At each interference level leading up to loss of lock, reacquisition time, fundamental GPS measurements (e.g., pseudorange and carrier phase), status flags (e.g., potential cycle slips), and position data were sampled. A variety of UWB signals were tested, including aggregates of as many as six UWB sources. Two GPS receivers with different receiver architectures were tested.

Key words: Global Positioning System (GPS), Ultrawideband (UWB), Impulse Radio, Amplitude Probability Distribution (APD), Interference Measurement, Noise, Radio Frequency Interference (RFI)

1. INTRODUCTION

As new wireless applications and technologies continue to develop, conflicts in spectrum use and system incompatibility are inevitable. This report investigates potential interference to Global Positioning System (GPS) receivers by ultrawideband (UWB) signals. According to Part 15 of the Federal Communications Commission (FCC) rules, non-licensed operation of low-power transmitters is allowed if interference to licensed radio systems is negligible. On May 11, 2000, the FCC issued a Notice of Proposed Rulemaking (NPRM) [1] which proposed that UWB devices operate under Part 15 rules. This would exempt UWB systems from licensing and frequency coordination and allow them to operate under a new UWB section of Part 15, based on claims that UWB devices can operate on spectrum already occupied by existing radio services without causing interference. The NPRM calls for further testing and analysis, so that risks of UWB interference are understood and critical radio services, particularly safety services such as GPS, are adequately protected.

Conventional methods of measuring and quantifying interference under narrowband assumptions are insufficient for testing UWB interference. Recently, NTIA's Institute for Telecommunication Sciences (ITS) investigated general characteristics of UWB signals [2]. As a natural extension to the UWB characterization study, this investigation measures the interference from a representative set of UWB signals imposed on a select group of GPS

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receivers. The remainder of this section discusses the relevant technologies and associated applications, briefly summarizes related studies, and gives an outline for this report.

1.1 The Technologies

The multifaceted strategic and commercial importance of GPS and the potential commercial importance of UWB are summarized in the following subsections.

1.1.1 Global Positioning System

The Global Positioning System has emerged as a universal cornerstone for much of our technological infrastructure. GPS is a space-based, broadcast-only, radio navigation satellite service that provides universal access to position, velocity, and time information on a continuous worldwide basis. The GPS constellation consists of twenty-four satellites that transmit encrypted high-precision pseudo-random noise (PRN) codes (i.e., P(Y) codes), used by U.S. and allied military forces, and unencrypted coarse-acquisition PRN codes (i.e., C/A codes), which are used in a myriad of commercial and consumer applications.

GPS is a powerful enabling technology that has created new industries and new industrial practices fully dependent upon GPS signal reception. It is presently used in aviation for en-route and non-precision approach landing phases of flight. Precision-approach services, runway incursion, and ground traffic management are currently being developed. On our highways, GPS assists in vehicle guidance, and monitoring; public safety and emergency response; resource management; collision avoidance; and transit command and control. Non-navigation applications are often grouped into geodesy and surveying; mapping, charting, and geographic information systems; geophysical measurement and monitoring; meteorological applications; and timing and frequency. Planned systems, such as Enhanced 911, personal location, and medical tracking devices are soon to be commercially available. Moreover, the U.S. telecommunications and power distribution systems are also dependent upon GPS for network synchronization timing.

1.1.2 Ultrawideband Transmission Systems

Unlike conventional radio systems, UWB devices bypass intermediate frequency (IF) stages, possibly reducing complexity and cost. Additionally, the high cost of frequency allocation for these devices is avoided if they are allowed to operate under Part 15 rules. These potential advantages have been a catalyst for the development of UWB technologies.

UWB signals are characterized by modulation methods that vary pulse timing and position rather than carrier-frequency, amplitude, or phase. Short pulses (on the order of a nanosecond) spread their power across a wide bandwidth and the power density decreases. UWB proponents argue that the power spectral density decreases below the threshold of narrowband receivers, hence, causing negligible interference. Other advantages are mitigation of frequency selective fading induced by multipath or transmission through materials.

Existing and potential applications for UWB technology can be divided into two groups – wireless communications and short-range sensing. In wireless communications, it has been shown to be an effective way to link many users in multipath environments (e.g., distribution of wireless services throughout a home or office). In short-range sensing applications, it can be used for determining structural soundness of bridges, roads, and runways and locating objects and utilities underground. Potential automotive uses include collision avoidance systems, air bag proximity measurement for safe deployment, and fluid level detectors. UWB technology is being developed for new types of imaging systems that would assist rescue personnel in locating persons hidden behind walls, under debris, or under snow.

1.2 Brief History of GPS versus UWB Compatibility Measurements

There are other measurement efforts underway to assess the potential for compatibility between UWB devices and existing GPS receivers. The Department of Transportation (DOT) has sponsored a GPS/UWB compatibility study at Stanford University, focusing on precision-approach aviation receivers that conform to the minimum operational performance standards. The general test procedure was a conducted experiment and utilized a radio frequency interference (RFI) -equivalence concept to relate the impact of UWB signals on GPS to that of Gaussian noise. A second measurement effort at the Applied Research Laboratories of the University of Texas at Austin (ARL/UT) was sponsored by the Ultra-Wideband Consortium. ARL/UT collected fundamental GPS parameters under conducted, radiated, and live-sky conditions for assessing single- and aggregate-source UWB interference to GPS receivers. Data analysis, however, was left to be performed by the GPS and UWB communities.

1.3 Scope

The objective of this study was to measure the degree of interference to various GPS receivers from different UWB signals. Recommendations on UWB regulation are left to the policy teams at NTIA’s Office of Spectrum Management (OSM) and the FCC. These measurements were designed to observe and report on broad trends in GPS performance when subjected to UWB interference. No attempt was made to evaluate specific receiver designs or interference mitigation strategies or provide precise degradation criteria.

1.4 Organization of this Report

Investigation of UWB interference to GPS receivers encompasses a broad range of expertise including GPS theory and operation, radio frequency (RF) design and hardware implementation, automated measurement development, temporal and spectral characterization of interfering signals, and statistical error analysis. This report completely describes the experiment and is organized as follows.

The first three sections provide orientation and background for the reader. Section 2 describes the characteristics of GPS signals, identifies GPS vulnerability to noise and continuous-wave (CW) interference and describes the nature of UWB signals. Section 3 discusses, at a high level, the general methodologies for measuring GPS performance degradation and describes GPS performance metrics.

Section 4 describes the GPS Interference Test Fixture, experimental procedures, categorization of tested GPS receivers, selected UWB signal parameters, calibration details, signal generation, and power settings. Section 5 describes the methods used for analyzing the collected data. Section 6 displays the experimental results which summarize trends in performance degradation. Conclusions are drawn in Section 7.

Appendices are provided for comprehensive purposes and contain supporting information and detailed measurement results. Appendix A is a comparison between radiated and conducted UWB interference tests. Appendix B describes hardware specifications and settings for the RF components of the test fixture, UWB signal generation equipment, and GPS receivers. Appendix C and D provide measured and theoretical characteristics of all the UWB signal types under test. Appendix E is a brief tutorial on the amplitude probability distribution (APD) which is an important method for characterizing UWB signals. Finally, Appendix F contains a complete set of GPS/UWB interference analysis plots.